VentSimWeb: Distributed Access to a Model of Cardiopulmonary Physiology

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Critically ill patients in the intensive-care unit (ICU) are treated by ICU staff, who must reassess patients frequently and interpret patient data from bedside monitors, mechanical ventilators, and laboratory tests. An automated monitor for patients in the ICU that applies advanced methods of ICU-data analysis and interpretation may improve clinical care of ICU patients. We are developing a patient monitor that will gather multiple measurements as they become available in the ICU, determine the meaning of the measurements with reference to each patient's clinical problem, and suggest appropriate settings for the mechanical ventilator.

The automated monitor of ICU patients relies on a detailed simulation model of cardiopulmonary physiology to interpret the physiologic implications of ICU-patient data. This physiologic model has a high computation complexity, which leads to a formidable computation challenge when we apply the model in the real-time ICU environment. The need for a powerful computation engine for the model simulations led to the desire for a distributed access to the model simulations, so that the model simulator could run on a more powerful remote computer, and yet be accessible to all ICUs in the hospital.

VentSimWeb is a world-wide web interface to our simulation model; the interface allows clinicians to explore the predicted effects of alternative ventilator-control settings. This simulation capability is an important function of the ICU-patient monitor, because these simulations allow a clinician to determine if the assumptions and simplifications that the physiologic model makes are valid for a specific patient. In addition, the interface allows a clinician to explore the space of possible ventilator settings to compare her preferences for ventilator settings with the recommendations of the automated monitor.

VentSimWeb accesses the VentSim model—a set of linked first-order differential equations that describe the circulation of oxygen and carbon-dioxide through multiple airway and circulation compartments.[1] The model includes a ventilator component, an airway component, and a circulation component. The ventilator component predicts the pressures and airflows that are generated by a volume-cycled, constant-flow ventilator. The airway component has anatomic and physiologic deadspace compartments, and two alveolar compartments that participate in gas exchange with two pulmonary blood-flow compartments in the circulatory component. The circulatory component also has a shunt compartment that allows a fraction of blood flow to bypass gas exchange in the lungs, and a tissue compartment that consumes oxygen and generates carbon dioxide.

The current version of the interface allows users to select one of ten patient diagnoses, enter values for six controls of the ventilator, and inspect (or adjust) seven parameters of the physiologic model.

The VentSimWeb simulator can be accessed by any computer that has a web browser (such as Netscape) and a connection to the Internet, at the URL: <http://smi.bih.harvard.edu/VentSim.html>.

VentSimWeb: An Online ICU-Patient Simulator

1. **Select a diagnosis:** Normal

2. **Set the ventilator controls:** Reset to initial values.

FIO2:	0.21	fraction (0.21-1.0)
Rate:	10	breaths per minute (2-30)
Tidal Volume:	12.0	deciliters (1.0-30.0)
PEEP:	0	cms H2O (0.-30.)
Max Insp Pressure:	50.	cms H2O (0.-100.)
IE ratio:	0.5	fraction (0.-1.)

3. **Run the simulator:** GO!

4. **Examine the predictions:**

Arterial Blood Gas			Mixed Venous Blood Gas			Airway pressures	
PaO2	PaCO2	pH	PvO2	PvCO2	pH	peak	mean
64.7	38.7	7.4	45.2	58.9	7.38	16.8	8.4

We would appreciate feedback! Send email to the VentSimWeb project

Figure 1. A portion of the VentSimWeb main page, from which users can select a diagnosis, change ventilator settings, run a simulation, and inspect the predicted effects of the ventilator settings.

1. Rutledge, G.W., VentSim: A Simulation Model of Cardiopulmonary Physiology. *Journal of the American Medical Informatics Association.* Symposium supplement:878–883, 1994

0195—4210/96/$5.00